Cybersecurity in Power Systems

A view on regulation and standardization

Steffen Fries, Siemens, T CST
Abstract

Power systems as one critical infrastructure demand specific consideration regarding their reliable and resilient operation. Cybersecurity is one functionality supporting this operation and is increasingly demanded by regulation.

To cope with these requirements, different standard (frameworks) have been developed. They address technical and procedural requirements as well as technical specifications to ensure interoperability between different vendors products. Moreover existing standards are renewed or enhanced to address upcoming requirements and advances in cybersecurity.

The presentation provides an overview of regulative requirements and solution standards ensuring secure operation of the electrical infrastructure. Besides this, examples are provided for challenges, requiring further investigation and solution discussion and development.
Businesses and Services of Siemens AG

**Industrial Business**
- Digital Industries
- Smart Infrastructure
- Mobility
- Siemens Healthineers\(^1\)
- Portfolio Companies
- Siemens Advanta

**Services**
- Siemens Financial Services
- Siemens Real Estate
- Global Business Services

\(^1\) Publicly listed subsidiary of Siemens; Siemens’ share in Siemens Healthineers is 75%
Charter of Trust
A joint initiative for a secure sustainable digital world

Associated Partner Forum

01
Protect the data of individuals and businesses

02
Prevent damage to people, businesses, and infrastructure

03
Build trust in the digital world
Company Core Technologies
Innovation examples

**Simcenter ROM Builder**
- Creation of simplified, tool-neutral and reusable models by processing simulation and field data
- Model generation accelerated (up to real-time), interoperable, and deployable from simulation to edge and cloud

**OT Security Appliance (OSA)**
- Comprehensive asset discovery and security monitoring of industrial automation networks and applications
- On-site security monitoring during ongoing industrial operations and AI for behavior-based anomaly detection

**Reliable power with renewable generation**
- Assistant for power system operation with up to 100% renewable peak generation
- Collaborative stabilization and resilience of entire island grids (e.g. Hawaii)
- Capacity can be scaled up to a range between 100 MW and 100 GW

**SiGREEN**
- Trustworthy exchange of actionable Product Carbon Footprints throughout value chains
- Use of verifiable credentials ensures transparency, confidentiality, and data control in supply chains
Digital Grid – a Critical Infrastructure in Need of Protection

Power system value chain and use case examples

High Voltage
≥ 100kV

Medium Voltage
20kV … 100kV

Low Voltage
≤ 400V

Transmission Substation

Distribution Substation

Generation
• Power Quality Monitoring
• Network Optimization

Transmission
• Substation Automation
• Inter Control Center Communication
• Remote Maintenance and Service

Distribution
• DER Integration (Metering & Control)
• Remote Services

Prosumer
Consumer / Producer

Rail & Microgrids
• Connecting Electric Vehicles to the Charging Infrastructure
Security must be (continuously) adopted to the changing threat and vulnerability landscape

1950s – 1960s
Military, governments and other organizations implement computer systems

1970s
Home computer is introduced

1980s
Computers make their way into schools, homes, business and industry

1990s
Digital enhancement of electrification and automation

1991
The World Wide Web becomes publicly accessible

1999
The globe is connected by the internet

2000s
Mobile flexibility

2010s
Cloud computing enters the mainstream

2020s
Internet of Things, Smart and autonomous systems, Artificial Intelligence, Big Data

Digital Information Processing
Digital Connectivity
Digital Automation and Artificial Intelligence

1999
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Internet of Things, Smart and autonomous systems, Artificial Intelligence, Big Data
How to provide appropriate cybersecurity?
Cybersecurity needs a holistic methodology

Recover
Creating plans for resilience and **restoration** of any capabilities or services that were impaired due to a cyber security related event.

Respond
**Taking action** against detected cyber security related events. Supports the ability to contain the impact of a potential event.

Detect
Rapid **identification** of the occurrence of a cyber security related event.

Identify
**Understanding** the business context, the resources that support critical functions and the related cyber security risks.

Protect
**Protection** of critical infrastructure service, e.g., energy supply by safeguarding the overall system.

The Five Functions are part of the NIST Cyber Security Framework.
Digital Grid as critical infrastructure is addressed through regulative requirements and standards (examples, global view)

Regulative Requirements
- Critical Infrastructure Protection (NERC CIP)
- Executive Order 13636 improving Critical Infrastructure Cyber Security
- Executive Order 14028 improving Nation’s Cyber Security
- IT Security Act
- B3S Standards
- BNetzA Security Catalogue
- German Energy Act
- Critical Infrastructure Protection
- Certification and Key Measures
- Cyber Security Act (CSA)
- Network Information Security Directive (NIS2)
- Cyber Resilience Act (CRA)
- Cyber Essential Scheme
- Direct adaptation of European NIS Directive and GDPR

International Standards
- Design details
- Technical aspects
- Relevance for products
- Operations
- Completeness
- Governance & policy aspects
- IEC 62351
- ISO/IEC 27001/2
- ISO/IEC 27019
- IEC 62443
- Direct adaptation of European NIS Directive and GDPR

Note: the stated organizations and standards are just examples and are not complete

Specifies security management requirements for manufacturers, operators, ...
IEC 62443 – Security for Industrial Automation and Control Systems
Addresses the complete value chain from product manufacturing to operation

- Targets operator, integrator, and product supplier in terms of processes and security capabilities and allows for certification

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<th>Component / Product</th>
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Selected Certificates issued to Siemens

- Certification relevance
- Published
- Functional
- Under revision
- Procedural
- In development / planned
IEC 62443 – Security for Industrial Automation and Control Systems
Enables a graded security approach to achieve appropriate protection
Core Communication Standards for Digital Grids
IEC TC57 defines the reference architecture with domain-specific cybersecurity

- Development of IEC 62351 to secure communication protocols defined by IEC TC 57, specifically
  - IEC 60870-5 and IEC 60870-6 series,
  - IEC 61850 series,
  - IEC 61968 & IEC 61970 series.
- Undertake the development of standards and/or technical reports on end-to-end security issues.
  End-to-End Security = a set of security policies, procedures, and technologies that provides a high degree of assurance that data exchanged between a source (sender) and a sink (receiver) is protected from unauthorized access and/or modifications, while being transferred from one end to the other through intermediate nodes.
- Addressed in currently 18+ parts of IEC 62351 of different status

1 RBAC = Role-based Access Control
Cyber security is addressed in power system automation through IEC 62351
Building on state of the art security technology

IAM – Authentication, Identification
Authorization (RBAC) of Users/Devices
Focus: Usage of X.509 certificates

Secure communication between different actors (Ethernet, IP, serial)
Focus: Profiling of existing standards (e.g., TLS) and definition of security enhancements if necessary

Monitoring and audit of security relevant events
Focus: Application of established standards like syslog and SNMP

Key management of long term and session keys
Focus: Application of established certificate management (EST, SCEP) and key management (GDOI) protocols

Test case description for the specified security measures in the different parts of IEC 62351
Focus: Specification of conformity test cases

Guidance and support for securing power system
Examples comprise role based access control (RBAC), Monitoring of communication connections, …
Cyber security in Digital Grids
IEC 62351 provides technical security measures and guidelines

Security means defined for
- Authentication and authorization (RBAC)
- Secure IP-based and serial communication
- Secure application level exchanges
- Security monitoring and event logging
- Test case definition
- Guidelines for applying specific security measures

by utilizing or profiling
- existing standards and recommendations
IEC 62351 Application Examples
Role-based access control to power systems and services with PULL

LDAP repository is used to store IEC 62531-8 access tokens containing RBAC information as:
- PK-Certificate
- Attribute-Certificate
- JWS Token

1. User requests access to IED with username and password
2. Authentication request with username, password via LDAP
3. Users access token as response from LDAP repository after successful authentication
4. Success/Fail Response from device to user
5. Role-based user session initiated/denied

<table>
<thead>
<tr>
<th>Role to Permission mapping</th>
<th>Operation A</th>
<th>Operation B</th>
<th>Operation C</th>
<th>Operation …</th>
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<tr>
<td>Engineer</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
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<tr>
<td>Admin</td>
<td>X</td>
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<td>...</td>
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Different Security Standards meet in the Operational Environment
Application of IEC 62351 in a digital substation

Specification of technical solutions for an infrastructure supporting certificate-based authentication and authorization (PKI, RBAC)

IEC 62351-8/9

Monitoring & Audit Adaptation and enhancement of existing infrastructures and technologies for network management using SNMP and syslog

IEC 62351-7/14

Protection of process level and field level communication with real-time constraints using appropriate security measures

IEC 62351-3/4/5/6/9

Securing telecontrol and control center communication using TLS and/or security measures on application level

IEC 62351-3/4/5/9

Additionally, certification of security functionalities is possible to underline a security-aware development and integration process as well as support of technical security means (e.g., using IEC 62351).

Certification possible according to IEC 62443
**Security Requirement Consideration in Development and Feature Set definition** on the example of a protection device

- **Mutually authenticated and encrypted communication line** for operational protocols and engineering.
- **Device-side support for role-based access control** including central user management and emergency access.
- **Recording of security-relevant events and alarms** over Syslog and in non-volatile security log in device.
- **Confirmation codes for safety-critical operations**.

**SIPROTEC 5**

**Technical Measures according to IEC 62351**

- **Secure development**
- **Patch management**
- **Virus protection**

**Measures for product lifecycle supported by requirements from IEC 62443**

- **Product hardening**
- **Independent testing**
- **Crypto-chip for secure information storage and transmission**
- **Device uses key stored in crypto-chip to allow only firmware signed by Siemens to load**
- **Separation of process- and management communication**
- **Secured access for HMI interactions and web-based device monitoring**

**X.509 Certificates applied**

**Bay level**
Cybersecurity in the Power Grid
Security by Design in Products

- **Signed software/firmware**
  - Protection against firmware/software manipulation

- **Firewall & VLAN**
  - Separation of Ethernet traffic over integrated firewall & VLAN

- **Security Logging**
  - Non-volatile persistence of security audit trail and transfer over Syslog

- **RBAC with central user management**
  - Centrally manage users and assign roles for authorization (based on IEC 62351-8)

- **Certificate Management**
  - Easy X.509 certificate management with SICAM GridPass

- **Gateway Features in SICAM A8000 & PAS**
  - - VPN & TLS security
  - - Secure IEC 80670-5-104, IEC 61850, DNP3i
  - - Hardware-based application layer firewall in SICAM A8000
  - - Intrusion Detection

- **BDEW Whitepaper and IEC 62443 conformity**
  - Fulfills recommendations for control and communication systems security
Cybersecurity for Power System Automation
Interplay of ISO/IEC 27001 / IEC 62443 / IEC 62351

Cyber Security regulation are provided for instance by
- European NIS Directive and derived country specific laws
- US FERC for North America

### Procedural
- e.g.: ISMS for operator, or requirements for the development process for integrators and manufacturers

### Functional
- e.g., security levels, strength of security measures

### Technical
- e.g., security measures implementation, support interoperability

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**Asset Owner Operator**
- IT Infrastructure
  - ISO/IEC 27001
  - ISO/IEC 27019

**Integrator**
- IT Infrastructure
  - IEC 62443-2-4
  - IEC 62443-3-3
  - IEC 62351

**Product Supplier**
- IT Infrastructure
  - IEC 62443-3-3
  - IEC 62443-4-2
  - IEC 62443-4-1
  - IEC 62351
All good?
Well, there are still Security Challenges!

- **Operational challenge** to migrate existing systems to utilize specified security standards and BCPs.
- Observation of **System Integrity** to identify unauthorized (and also unintended) changes in system configuration. This may be connected with response handling upon detection.
- Ensuring **Resilience** to allow a system to stay operational with a degraded performance or functionality even when it has been attacked successfully.
- Performing **Monitoring** of industrial communication to ensure reliance with the intended operational environment even if the communication is encrypted. Influences on network design and privacy to be obeyed.
- Support of **Crypto Agility** to enable migration to stronger cryptographic algorithms. Advances in quantum computing endangers specifically asymmetric cryptographic algorithms like RSA or Elliptic Curve Cryptosystems (ECC) used for authentication, authorization, and key agreement in devices and infrastructure.
- Address **Supply Chain Security** requirements to enable verification of the system integrity along the product value chain and also after commissioning during operation.
Summary & Outlook

- Cybersecurity has been acknowledged as prerequisite for limiting risks in critical infrastructures.

- Regulation increasingly requires to address technical and organizational cybersecurity measures to ensure reliable operation of critical infrastructures and beyond.

- Standardization and guideline activities support the alignment of approaches and interoperability of different vendor’s products and need to adopt upcoming new requirements.

- Security-by-Design is essential to provide appropriate security features from the ground and addresses functional requirements as well as procedural means during product manufacturing and operation.

- Cyber security needs a holistic approach – collaboration between vendors, integrators and operators; taking into account people, processes, and products in the specific domain.

- Still, some challenges remain and provide further food for thoughts.
Contact

Steffen Fries
Principal Key Expert

T CST
Otto-Hahn-Ring 6
81739 Munich
Germany

E-mail steffen.fries@siemens.com

Siemens Grid Security
Siemens Cyber Security
Information

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